SOME DYNAMIC PHENOMENA SHOWN BY THE BARABOO QUARTZITE RANGES OF CENTRAL WISCONSIN.

THE quartzite ranges of Baraboo extend east and west for about thirty miles, one lying north, and the other, the main range, lying south of the City of Baraboo. The geology of this district is admirably given by the late Professor Irving.[1] Not only is the general geology clearly described, but remarkably accurate descriptions are given of the character of the quartzite, and the phenomena shown by it, considering the fact that the report was written nearly twenty years since. The unconformity existing between the quartzite and the Cambrian was later more fully described.[2] The induration of the Baraboo quartzite has been explained as due to the enlargement of the original quartz grains; and to the deposition of independent interstitial quartz.[3] The present note is based upon recent observations on the East Bluff at Devil's Lake and on the exposures at the Upper Narrows of the Baraboo River.

The section across the ranges, as given by Irving, is shown by Fig. 1. The two ranges together, as thus represented, are less than the north half of a great anticline, the south side of the south range being near its crown. This structure involves a very great thickness of quartzite, and was offered with reservation by Professor Irving. He says: "The hypothesis is not altogether satisfactory. The entire disappearance of the other side of the great arch, as well as the peculiar ways in which the

[1] The Baraboo Quartzite Ranges, by R. D. Irving. In Vol. II, Geol. of Wis., pp. 504–519.

[2] The Classification of the Early Cambrian and pre-Cambrian Formations, R. D. Irving. In 7th Annual Rep., U. S. G. S., pp. 403–408.

[3] Enlargement of Quartz Fragments and Genesis of Quartzites, by R. D. Irving and C. R. Van Hise. In Bull. 8, U. S. G. S., pp. 33, 34.

ranges come together at their extremities are difficult to explain by it. It may be said in this connection that the dip observations toward the west are not so satisfactory or numerous as they might be." The question naturally arises whether or not the great width of the ranges in the central part of the area may not be partly explained by monoclinal faulting, and thus reduce the supposed thickness of the beds.

The layers of quartzite are ordinarily very heavy, but the changing character of the original sediment is such as to make it easy to follow the layers. Some beds were composed of fine

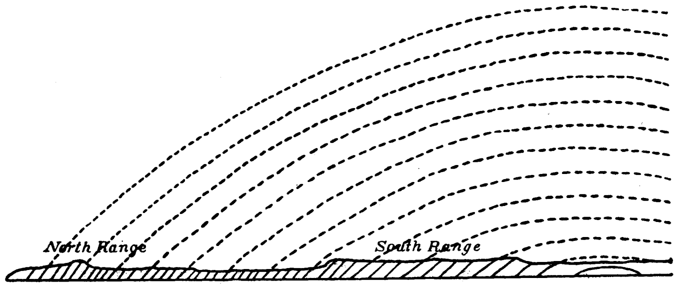

FIG. 1.—Ideal Sketch, showing structure and amount of erosion of the Barboo Ranges. After Irving.
Scale natural, 12,000 feet to the inch.

grains of quartz, mingled with clayey material, others of coarse grains with little clayey material, and others of pebbles so large as to pass into an unmistakable conglomerate. The pebbles of the conglomerate are mainly white quartz and red jasper. It is thus easy to discriminate the bedding of the series from the heavy jointing which occurs, cutting the bedding in various directions, and from a secondary cleavage and foliation which occurs in certain localities.

From the general work of many geologists on dynamic action in folding, it is to be expected that the amount of movement necessary for accommodation between beds, and consequently the dynamic metamorphism resulting from shearing, would be less near the crown of the anticline than on the leg of

the fold. That is, dynamic metamorphism ought not to be so extensive in the south range as in the north range. The facts described by Irving,[4] and those noted by me, fully agree with this anticipation. The central parts of the heavy, little inclined beds of the south range are largely indurated by simple enlargement. The pressure has not been sufficient to obliterate the cores, but has apparently granulated the exterior of some of the larger fragments, as in hand specimens the exteriors of the large blue quartz grains are white. Very generally the grains show slight wavy extinction. A few of them are distinctly cracked. The crevices thus formed and those in the interstices have been filled in large part by infiltrated silica, but their positions are plainly indicated by difference in extinction, by bubbles, by iron oxide, or by secondary mica which has taken advantage of the minute crevices.

However, as described by Irving, between the heavy beds of quartzites are often layers, cut by a diagonal cleavage which dies out in passing into the thick beds. The layers showing cleavage sometimes pass into those showing the beginning of foliation, the rock then nearing a schist. In the centers of the schist zones, the schistosity approaches parallelism with the bedding, and in passing outward curves from this direction until it crosses the bedding at an angle, at the same time becoming less marked and grading into ordinary cleavage, which dies out in the quartzite. Upon the opposite side the transition is of the same character, but the curve is in the opposite direction.

Irving apparently regarded these shear zones as originally beds of a different character from the adjacent quartzite, and his conclusion is fully borne out by the thin sections. The microscope shows that the grains of quartz are of small size, and separated to a greater or a less extent by interstitial clayey material. Because of this partial separation of the grains of quartz, they have not been granulated to the extent that one would expect from the schistosity of the rock, most of the original

[4] The Baraboo Quartzite Ranges, by R. D. Irving. In Vol. II, Geol. of Wis., pp. 510, 516.

cores being plainly visible. They, however, often show wavy extinction and even cracks, but not to a greater degree than the grains in the massive quartzite; for in the latter the full stress of the pressure has been borne by the grains in full touch, not separated by a plastic matrix, as are the grains of quartz in the argillaceous layers. In the matrix of the schist are numerous small flakes of muscovite, arranged with their longer axes in a common direction, much finely crystalline quartz, and a good deal of iron oxide.

It is concluded that the clayey character of the beds, and, consequently, the greater ease of movement within them, has located the slipping-planes and shear-zones, necessary in order to accommodate the beds to their new positions. On the south range, near Devil's Lake, these shear-zones are generally not more than six or eight inches wide. They may be well seen just back of the Cliff House, and on the Northwestern Railway, about one-half mile south of this house. All of these shear-zones are parallel with the bedding, and illustrate the possibility, so far as I know first mentioned by H. L. Smyth, that a crystalline schist, with schistosity parallel to bedding, may be produced by shearing along the bedding-planes.

On the railroad track, near the locality where these shear-zones may be seen, is also an almost vertical shear-zone, two to four feet wide. It therefore cuts almost directly across the beds of quartzite, which here incline to the south about twelve or thirteen degrees. Throughout this band, the quartzite is broken into angular trapezoidal fragments, the longer directions of which are vertical, and which may be picked out with the hammer. In certain parts of the zone well-defined gruss or friction clay, produced by the grinding of the fragments against one another, has been produced. This is clearly a plane of faulting. How much the throw of this fault is it is not easy to say, as the heavy beds of quartzite are so similar that it is impossible to certainly identify them. At this place there is, however, a change in the character of the quartzite, layers of light color being overlain by other beds, which are more heavily stained with iron oxide. This

same succession is seen on both sides of the fault, and if beds of like character correspond, the amount of the throw is twenty to thirty feet, and the south side has dropped relative to the north side. In other words, the faulting is in the right direction to reduce the theoretical thickness of the sediments as given by Irving. The district has not been closely examined for other faults, but the existence of one fault, even of a minor character, suggests that a careful study of the whole area with reference to faulting should be made, in order to determine what deductions may possibly be made from Irving's estimate of the probable thickness of the quartzite.

At the upper narrows of the Baraboo, near Ablemans, we are on the north leg of the anticline. The dip is throughout from seventy to ninety to the north, and in some places the layers are slightly overturned. The slipping along the bedding has here been much greater. While in this area there are heavy beds of quartzite which have not suffered great interior movement, other beds have been sheared throughout, being transformed macroscopically into a quartz-schist, but the foliation is strongly developed. In other places, as described by Irving,[1] where the rock is a purer quartzite, for a distance of 200 feet or more across the strike, the rocks have been shattered through and through, and re-cemented by vein quartz.

For the most part the rock is merely fractured, the quartz fragments roughly fitting one another, but there are all gradations from this phase to a belt about ten feet wide of true friction conglomerate, the fragments having been ground against one another until they have become well-rounded (a Reibungs breccia). Between the boulders of this zone is a matrix, composed mainly of smaller quartzite fragments. The whole has been re-cemented, so that now the mass is completely vitreous. This belt of friction conglomerate at first might not be discriminated from the Potsdam conglomerate, immediately adjacent, but a closer study shows how radically different they are. In

[1] The Baraboo Quartzite Ranges, by R. D. Irving. In Vol. II., Geol. of Wis., p. 516.

one the cementing material is vein-quartz; in the other the sandstone has been feebly cemented by quartz enlargement.

A movement later than the one which produced the cemented fractured rocks and breccia has broken broad zones of the massive beds of quartzite into lozenge-shaped blocks, the longer axes of which are parallel to the bedding and movement. These later-formed blocks have not been re-cemented by secondary quartz, and the cracks are taken advantage of in quarrying, the fragments being easily picked apart. Thus the rock has been affected by at least two dynamic movements, separated by a considerable interval of time.

The shear-zones, often several feet in width, particularly affect the more finely-laminated layers, which are lean in quartz, while the relief in the more massive layers has resulted in complex fracturing. In the first phase of production of the schist, the irregular fractures pass into rather regular fractures, cutting the beds nearly at right angles. As the action becomes more intense in the more argillaceous beds, the angle of fracture, or cleavage, as it may now fairly be called, becomes more acute, and in the most intense phase this cleaved rock passes into a well-developed schist, the foilation of which is parallel to the bedding. The phenomena of shearing are here therefore very similar to those at Devil's Lake, except that the process has gone farther.

When studied in thin section, the massive beds of quartzite show more decided effects of dynamic action than at Devil's Lake. However, the major portions of the grains of quartz have distinct cores which are often beautifully enlarged. In some cases nearly every grain has thus grown, perfectly indurating the rock. But, also, nearly every grain of quartz has a wavy extinction, and many of them have been fractured, as mentioned of a few of the quartz grains of the quartzites of the south range. In one case the pressure has been so great as to produce rather numerous roughly parallel lines of fracture. It is thus seen that the dynamic effects are not confined to the schist zones, but are also prominent within the heavy beds of quartzite. This was to

be expected; for while the major part of the accommodation necessary to bend the rock mass as a whole took place along the shear zones, the accommodation required to bend each of the rigid heavy beds of quartzite must have taken place within each layer. To the consequent intense pressure and the rubbing of the grains over one another, are wholly attributed their wavy extinction and fractures.

In the schists of the shear zones, as at the south range, the thin sections show that the original quartz grains were small; interstitial material was present, and mica has developed more largely than in the quartzite. However, in the most crystalline phases, the fragmental cores of the quartz grains and their frequent enlargements are plainly seen. Thus the shearing has not been sufficient to produce a completely crystalline schist, although this would not be macroscopically discovered, unless it were suspected because the rock is not thinly foliated.

As the dip of the quartzite is so steep at this locality, it is difficult to say how far the shifting of the beds over one another lessens the apparent thickness. The shear zones as well as the friction conglomerates appear to be parallel to the bedding. If they are exactly so, this shearing action would necessitate an estimate of the original thickness greater than now shown, since the shear zones probably have less width at the present time than the beds from which they were originally produced.

Cutting the bedding are heavy joints inclined to the north at an angle of 20° to 30°. If slipping had occurred along these in the right direction, this might cause a small thickness of beds to have a great apparent thickness. However, the schists above described weather out on the face of the cliffs, and are therefore marked by recessions in the walls. If slipping parallel to the jointing had occurred since the schists were formed, these depressions ought not to match on opposite sides of the joints; but, on the contrary, they continue unbroken from foot to top, and probably the joints were formed simultaneously with or later

than the belts of schist. Consequently, at the upper narrows of the Baraboo no evidence was found of faulting which could reduce the estimated thickness of the quartzite as given by Irving.

As Irving clearly saw, bearing strongly in favor of the theory of a great fold, is the increasing steeper dip of the layers in passing north. The phenomena of movement and metamorphism corresponding so exactly to those required by a simple fold, the question may be asked if these are not evidence of some weight in favor of the general correctness of Irving's conclusion as to the structure. Had monoclinal faulting extensively occurred, it would not have been necessary to have had so great a readjustment of the beds as has been shown to occur by the schists, cleavage, and the exceedingly intricate macro-fracturing and micro-fracturing of the rock beds and their constituent particles.

In addition to the phenomena described by Irving, in summary, the Baraboo quartzite ranges show results of dynamic metamorphism as follows: A fine example of the Reibungs Breccia may be seen. A fault zone of limited throw exists. All phases are exhibited, between a massive quartzite, showing macroscopically little evidence of interior movement through a rock exhibiting in turn fracture and cleavage, to a rock which macroscopically is apparently a crystalline schist. The foliation of the schists is parallel to the original stratification, being consequent upon the movements of the beds over one another, readjustments occurring mainly in the softer layers. In thin sections the schists still give clear evidence of their fragmental origin, but also show the mechanical effects of interior movement. These same effects are apparent within the heavy beds of quartzite, some readjustment of the particles to their new positions being here also necessary. There is no evidence that the semi-crystalline character of the schist and quartzite are due to high heat. Nowhere are the particles fused. So far as they are destroyed it is by fracture, and the rock is again healed by cementation.

The rock, in its most altered condition being a semi-crystalline schist, and in other parts showing less change, can be connected with its original state. Had the folding been more intense, it is reasonable to suppose that the entire rock would have been transformed into a completely crystalline quartz-schist, showing no evidence of clastic origin, and possibly the foliation throughout would have corresponded to the original bedding.

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